A precise definition of habitat is needed for effective conservation and communication

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ABSTRACT

"Habitat" is often used ambiguously in conservation biology and ecology to mean either the specific biotic and abiotic parts of the environment where an organism lives (e.g., the habitat of species x), or to describe a particular environment without reference to a specific species (e.g., the coastal dune habitat). Conservation legislation usually defines habitat as a function of the species, as do botanists, while zoologists are more likely to use habitat to mean a particular environment. We argue that this ambiguity can cause confusion in applied conservation and support defining habitat as "the environment of a species, and particularly those features that determine where the species occurs".

Key words: habitat, environment, botany, zoology, conservation legislation

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Krebs (2001) describes habitat as... "any part of the biosphere where a particular species can live, either temporarily or permanently". Other text book definitions are similarly broad (see Table 1). In a seminal paper on habitat selection, Lack (1933) clearly used the word habitat in the sense of these descriptions, but defined an animal"s habitat precisely by elements such as food, shelter, nest site; even features as specific as a songbird"s calling perch. The Endangered Species Act of 1973 (USA) defines critical habitat of an endangered species as (section 5Ai): *the specific areas within the geographical area occupied by the species, at the time it is listed in accordance with the provisions of section 4 of this Act, on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection.* This is much more precise than textbook definitions and is consistent with Lack (1933). In comparison, the Australian Environment Protection and Biodiversity Conservation Act (1999) defines habitat as *"the biophysical medium or media: (a) occupied (continuously, periodically or occasionally) by an organism, or group of organisms; or (b) once occupied (continuously, periodically or occasionally) by an organism, or group of organisms; and into which organisms of that kind have the potential to be reintroduced."* This is less consistent with Lack (1933) than the definition under the USA"s Endangered Species Act, because the "biophysical medium" is vague, although it could refer to the "physical or biological features essential to the conservation of the species" used in the USA"s legislation. Both definitions define habitat as species specific, assuming that "an organism or group of organisms" means a species.

Many textbook definitions share the view that habitat is a function of the organism; in grammatical terms it is an adjective. Others in Table 1 are more descriptive, describing the environment available to animals. To continue the grammatical metaphor, habitat as a descriptor of a type of environment is a noun and is defined not by the organism using it, but by the environment recognised as a habitat type. Thus, there are descriptions of habitats such as "eucalypt forest habitat" (Lindenmayer *et al*. 2003), "spinifex habitat" (Barrow *et al*. 2007) and "mulga habitat" (Edwards *et al*. 2002). Habitat in this sense is a type of environment; no mention is made of animals. Thus the word habitat can be an adjective – a set of environmental features that characterise where a species can occur, or a noun – a type of environment. The use of habitat to mean a type of environment is refined in terms such as macrohabitat, mesohabitat and microhabitat, which refer to increasingly fine scales of where species might occur (e.g., Aadland 1993), while the use of habitat to mean where a species occurs has led to concepts such as habitat isodars (Morris 1989) and habitat isolegs (Morris 1999) which seek to model more precisely the characteristics of the environments organisms use, often as a means to better understanding of competitive interactions (Edwards *et al*. 2002).

Zoologists often use habitat to mean a type of environment (noun), whereas botanists mainly use habitat as an adjective. Thus, when a botanist was asked for the habitat of a plant, it was said to be "a particular association of environmental conditions including soil type, position in the topography and hydrological conditions" (G. Woodman pers. comm.). Allaby (1998) is unusual in drawing the distinction between botanical and zoological uses when defining habitat.

Habitat as a noun would not conflict with habitat as an adjective if a recognisable suite of animals used the same habitat (noun). This is untrue. Few animals are confined to one recognisable habitat (noun), let alone in common with a suite of other species. For example, the White-breasted Robin *Eopsaltria georgiana* occurs in the South-

Table 1. A selection of definitions of "habitat" from specialist dictionaries and textbooks. The sources were selected to give a wide range of years.

Source	Definition
Krebs (2001)	"any part of the biosphere where a particular species can live, either temporarily or permanently"
Knox *et al.* (2010)	"The environment of an organism; the place where it is usually found"
Villee (1972)	"The natural abode of an animal or plant species; the physical area in which it may be found."
Abercrombie *et al.* (1961)	"Place with a particular kind of environment inhabited by organism(s)."
Milne, L. and Milne, M. (1971)	"The place where an animal or plant is characteristically found….may be a geographical site recognisable from information about the non-living environment. Or may be described as a grassland, marsh or forest edge where deer are found."
Mader (2004)	"Place where an organism lives and is able to survive and reproduce."
Sadava *et al.* (2006)	"The environment in which an organism lives."
Campbell *et al.* (2009)	"A place where an organism lives; an environmental situation in which an organism lives."
Hickman *et al.* (2012)	"The place where an organism normally lives or where individuals of a population live."
Allaby (1998)	"The living place of an organism or community, characterised by its physical (for plants) or vegetative (for animals) properties."

West of Western Australia in Jarrah forest and in coastal woodlands and scrub-heaths. These are very different habitats (noun). Within the Jarrah Forest, *E. georgiana* occurs in dense riparian thickets. The riparian vegetation includes small trees (e.g., *Banksia seminuda*), tall shrubs (e.g., *Trachyandra linearifolia*), low shrubs and sedges. In the coastal woodlands and scrub-heaths, *E. georgiana* occurs in dense thickets around wetlands and in dunal valleys. The plant species and often genera are different from those in Jarrah Forest. The habitat (*sensu* Lack 1933, who uses it as an adjective) of *E. georgiana* is "dense, locally mesic thickets of varying floristics, particularly with perches for foraging". Higgins and Peters (2002) state that *E. georgiana* occurs in two different habitats, which is nonsensical if habitat is a function of the species but reasonable if habitat is a type of environment independent of the species. However, they go on to state that the species requires dense, moist vegetation irrespective of overstorey - a species-specific habitat description.

Several birds coexist with *E. georgiana* within riparian vegetation in the Jarrah Forest, (e.g. Red-winged Fairy-wren *Malurus elegans*, Red-eared Firetail *Stagonopleura oculata* and White-browed Scrubwren *Sericornus frontalis*), but only *S. frontalis* also occurs in mesic thickets around wetlands in coastal woodlands. Thus there is one other bird species associated with the habitat of *E. georgiana*, but not a consistent suite of species.

Similarly, many reptile species of Australian deserts are recognised as occurring in hummock grasslands formed of spinifex *Triodia* spp. (Pianka 1969). This spinifex can occur on sand, on rocky slopes, as an understorey component in eucalypt or acacia woodland, and in different climatic zones. As a result, the same reptile species may be present in quite different vegetation types and on different soil types because the spinifex provides the same environment. However, other factors may drive the distribution of reptile species even among those found in spinifex hummocks, and other species may be present because of other features of the environment such as sandy soil or leaf-litter derived from eucalypts. There is a suite of spinifex-dependent reptiles, but they do not occur consistently as an assemblage where spinifex occurs.

Habitat as an adjective transcends typical recognition of vegetation types because, as per textbook definitions, habitat is the environment utilised by an organism, and organisms rarely occupy the whole of an environment, such as a forest, but part of it. Perhaps this could be defined as micro-habitat, but that still implies some sort of consistency in fauna assemblage which isn"t the case, and one would expect micro-habitat to be a subset of the habitat, which is also not the case. If the habitat (dense, locally mesic thickets of varying floristics) of *E. georgiana*, is a micro-habitat, then one is left with a micro-habitat that is a subset of two different habitats.

A similar debate, with similar implications, is already occurring in relation to what Dobzhansky (1964, p.449) called the "unfortunately ambiguous and yet indispensable concept" of the niche. Chase and Leibold (2003) point out that some definitions of the niche view it as a property of the species (using our argument, as an adjective) while other definitions consider the niche as a property of the environment (as a noun). Townsend *et al.* (2011, p.7) rephrased the two positions as either "the functional role of an animal on a community (its local effects)" or its "climatic and habitat requirements (the environmental requirements) expressed geographically", before enlarging their considerations of geographic properties of niches. Just as niche theory is benefitting from a close re-examination of definitions to ensure precision in research, tightening the use of "habitat" may facilitate clearer thinking and communication.

Habitat in the sense of at least some textbooks, and certainly as used by Lack (1933), is clearly a property of the organism, which presents a problem because of the very widespread use of the term habitat to mean a type of environment. One of us (MJB) uses the term Vegetation/

Substrate Association (VSA) in an attempt to avoid this misuse of the word habitat. The term ecotype might be considered to mean the same thing, but implies some sort of biological integrity and excludes the geology of a site. Using a term like VSA does leave the word habitat (adjective) free to describe the environmental parameters that define where a particular species occurs, and allows statements such as that a certain VSA provides habitat for this or that species. Use of a new term might not be widely accepted, however, but is also not really necessary given that habitat (as a noun) is so easily replaced by environment or vegetation type.

Keeping to the strict (i.e. adjectival) sense of the word habitat may be important for legal interpretations under conservation legislation, and has potential management benefits. For example, kwongan (*Banksia* low woodland) may be conserved as a habitat type (noun), although subject to a range of management actions including use of underground aquifers or altered fire regimes that may change its suitability as habitat for specific organisms (habitat as a property of the organism) (Sommer and Froend 2011; Wilson *et al.* in press). Expressed this way, habitat as used by Lack (1933) is a powerful ecological term that focuses on what is needed to conserve fauna; habitat used to describe a type of environment is weak and redundant. We therefore propose a definition of "habitat" that makes it clear that this is a function of the species: "the environment of a species, and particularly those features that determine where the species occurs".

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